Improved Radio Astronomy Interference Characterization Using DevOps

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***Abstract*—In order to increase spectrum sharing and protect Radio Astronomy against ever increasing Radio Frequency Interference (RFI), it is important to constantly monitor and analyze the radio frequency environment. This research improves upon a Software Defined Radio (SDR)-based testbed deployed at the Hat Creek Radio Observatory for over a year now with real time monitoring through DevOps tools. Utilizing Docker, Ansible, Prometheus, and Grafana in addition to improvements on the code created to run these continuous radio frequency surveys, measurements are calculated and displayed within seconds. Ensuring the health of these devices both from tampering and time/wear is also of utmost importance given the nonstop data collection. To that end daily status checks, alerting, and daily liveness checks have also been implemented. All of this ensures the constant monitoring of RFI is reliable, allowing for improved data gathering and analysis.**

I. Introduction

Recognizing the critical need for effective spectrum sharing, the Wireless Interdisciplinary Research Group (WIRG) working group emphasizes its necessity for future access to radio spectrum. Continuous 24/7 RF surveys to monitor the spectral environment can benefit from Docker-based containerization, which enhances performance by streamlining resource allocation and improving system efficiency. Docker's ability to isolate and manage survey processes ensures a more stable environment, reducing risks to data integrity and reliability. This research seeks to enhance a Radio Frequency Interference (RFI) testbed at the Hat Creek Radio Observatory (HCRO) [1] by integrating DevOps tools such as Docker, Ansible, Prometheus, and Grafana. These tools not only streamline deployment and management but also significantly improve the stability and uptime of the continuous monitoring system. With real-time data collection and analysis capabilities, this enhanced testbed will enable rapid identification and measurement of RFI sources. Ultimately, the goal is to establish a national radio dynamic zone (NRDZ) to better coordinate activities between radio astronomy and active users.

II. Design

The architecture consists of several key components working together to ensure the health, performance, and updates of deployed RF sensors. The flow of data and updates between servers, monitoring tools, and deployed sensors is visually represented in Figure 1. The RF sensors are deployed in different locations, each associated with a Raspberry Pi (RPi). These sensors include designations based on their location at HCRO. Each sensor collects RF data and communicates with a centralized server. The Docker containers running on the RPis handle the core functions of data collection and communication. Data processing occurs in code ran in Docker containers on the server.

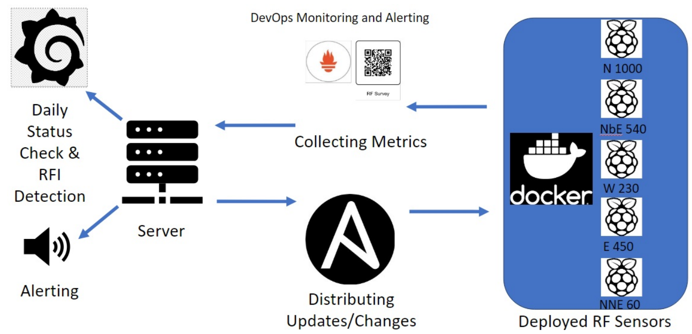

Fig. 1. Block diagram illustrating the DevOps architecture for RFI detection systems.

A. RFI Dashboard

The RFI detection dashboard shown in Figure 2 provides an ongoing visual overview of the RF survey data, monitoring signal strength, temperature, and interference over time across multiple deployed sensors. The top-left panel displays power levels over time for various sensors deployed in the RF survey. This enables the user to see how the power levels vary over time, with each line representing a sensor's data collection. With the spectral kurtosis graph in the bottom left, users track the intensity and frequency of interference over the survey period, enabling operators to identify when and where RFI occurs. The dashboard enables users to view historical data across the survey period, including the entire year of collected data but can also zoom in to see data points collected within seconds for other tests.

B. Daily Status Check

The daily status check report provides a comprehensive overview of the operational health of all systems and devices across various lab subsystems. It includes a Daily Summary highlighting the total RFI Events, Time Down, and Data Points Collected per sensor. Each device's status is color-coded (green, yellow, red) to indicate normal operation, warnings, or critical alerts. The report further breaks down detailed metrics for specific sites such as HCRO and CU Boulder, tracking key performance indicators like CPU temperature, disk space, downtime, and network availability. An additional

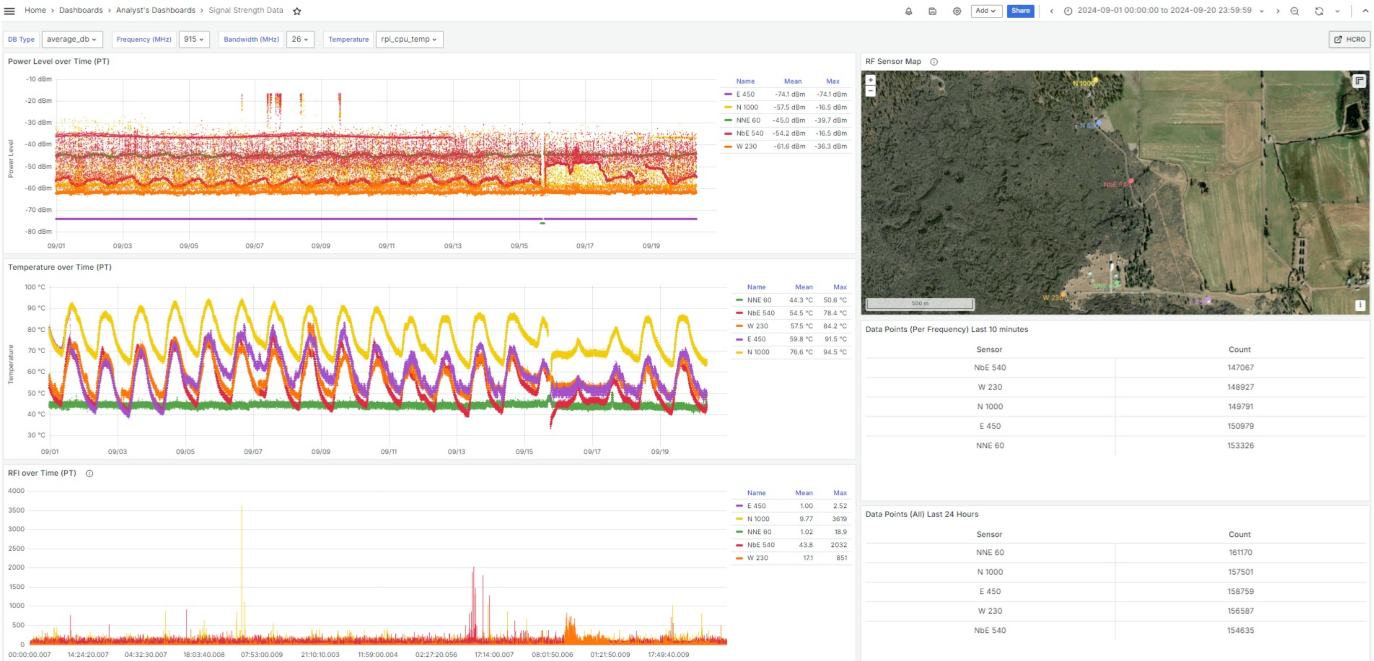

Fig. 2. The RFI detection Grafana dashboard for the month of September.

section for Satellite Spotting provides information on satellites passing through the system's frequency band, identifying any RFI bursts or notable occurrences. The summary ensures that team members stay informed on system performance, can quickly address any issues, and maintain smooth operational workflows.

C. Alerting

The Alerting Table is essential for monitoring the functionality of the RFI testbed surveys, providing a structured framework for categorizing operational status and identifying key personnel for notifications. Each level of alert defines specific conditions under which alerts are triggered, ensuring timely communication of issues. These criteria are integrated into our Grafana-based alerting system, which automatically sends emails or Slack messages to relevant stakeholders, enabling swift responses when the surveys encounter problems. This proactive approach enhances system reliability and ensures that any disruptions are promptly addressed.

D. Daily Liveness Check

The liveness check serves as an additional validation step to ensure that even if all RF surveys are running and the devices appear healthy, they are indeed collecting accurate and meaningful data. This process involves running Power Spectral Density (PSD) graphs, which are compared against a known signal baseline to verify that the antennas are capturing valid data. By cross-referencing the current survey outputs with expected patterns, the liveness check helps identify any inconsistencies, such as misalignment or signal degradation, that might not be immediately apparent through standard health checks. This ensures the integrity and reliability of the data collected during RF surveys.

TABLE I
ALERTING TABLE FOR RFI TESTBED FUNCTIONING.

Level	Name	Event
1	Nominal	All daily data points collected All systems operational No Alerts
2	Caution	<100% data points collected Time down <2 hours No Alerts
3	Warning	<50% data points collected Time down >2 hours Alerts
4	Error	<50% data points collected Time down >5 hours System Warning due to CPU overload, overheating, etc

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REFERENCES

[1] S. Tschimben, A. Aradhya, G. Weihe, M. Lofquist, A. Pollak, W. Farah, D. DeBoer, and K. Gifford, "Testbed for radio astronomy interference characterization and spectrum sharing research," in *2023 IEEE Aerospace Conference*, 2023, pp. 1–16.